HEAVY RAINFALL DURING MID-JANUARY ALONG THE PACIFIC COAST

GROVER D. HUGHES AND CHARLOTTE L. ROE

WBAN Analysis Center, U. S. Weather Bureau, Washington, D. C.

INTRODUCTION

After a dry autumn, January was a month of abnormal precipitation and high temperature [1] along the West Coast of the United States. Following comparatively light rains at the beginning of the month, precipitation steadily increased during the 2d and 3d weeks along the Oregon-northern California coast, reaching a maximum January 17–19. Cape Blanco, Oreg., for example, recorded over 14 inches of rain during these three days. This period was dominated by intense onshore winds and numerous frontal passages. The prolonged downpour, accompanied by strong lashing winds, resulted in heavy local flooding. Probably the greatest damage occurred to the highways where slides and washouts closed many roads and isolated some communities. Although heavy rains are not uncommon during the winter and are not unusually difficult to forecast, it will be of interest to investigate those features tending to sustain the precipitation for several days.

[1] See preceding article by Smith.

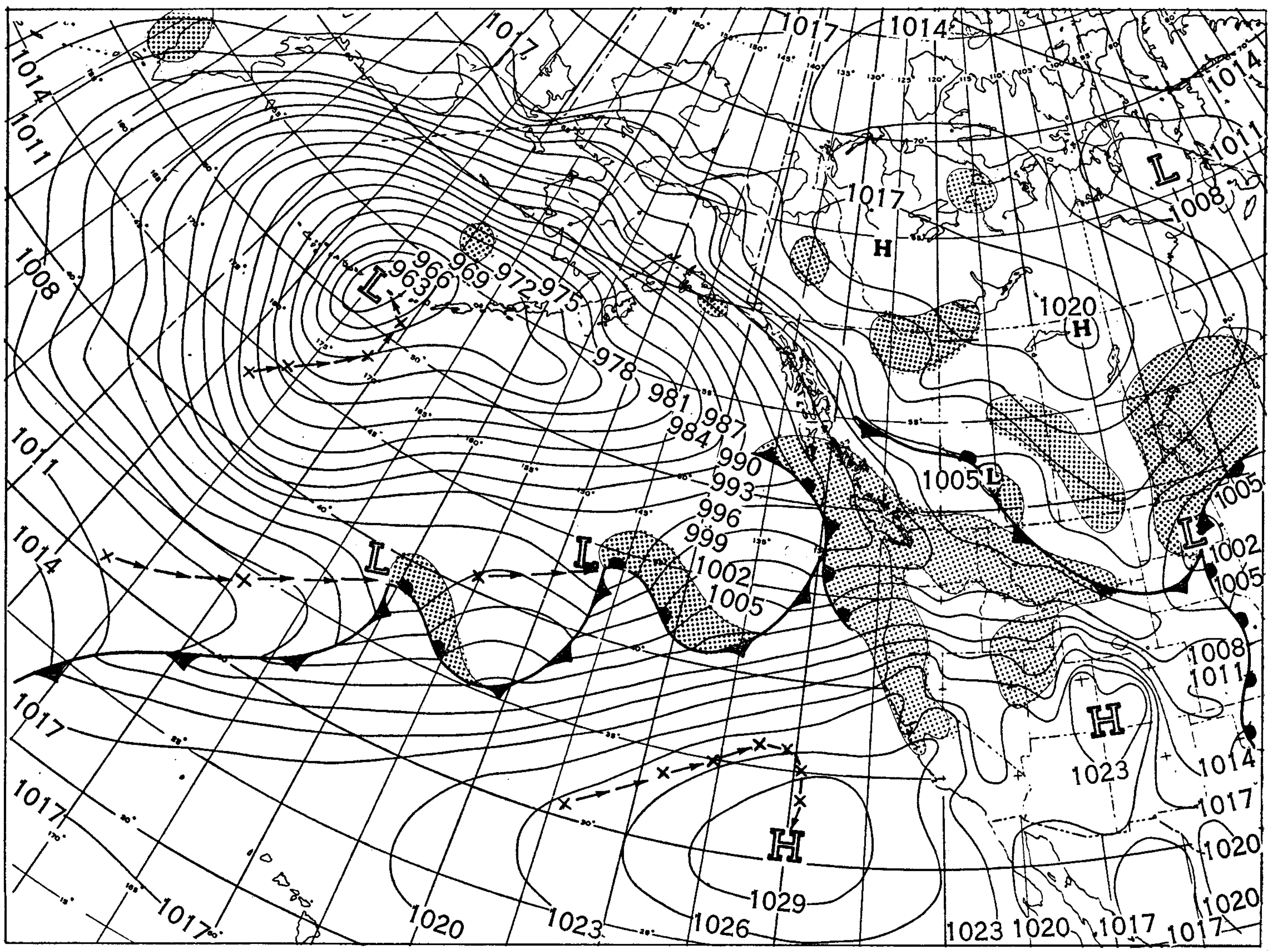

FIGURE 1.—Surface weather chart for 0030 GMT, January 18, 1953, illustrating the widespread cyclonic flow over the Northern Pacific. Shaded areas indicate active precipitation. Past positions are shown for 12-hour intervals.

METEOROLOGICAL CONDITIONS

During the first half of January, pressure ridge conditions aloft existed along the West Coast, deflecting into Canada the migratory surface systems moving toward the coast. The southern portion of the frontal systems weakened as they moved under the ridge aloft. During this period rainfall was relatively light along the Pacific Coast.

Near mid-January, a surface High, which had remained relatively stationary in northwest Canada during the first half of the month, began to move southward toward Alberta. Frontal systems were then forced to move inland at a lower latitude—namely between 40° and 50° N. Simultaneously, the portion of the Pacific High extending over the West Coast flattened, while the Aleutian Low deepened in the vicinity of 50° N., 170° W. The entire Pacific north of 35° N. was, therefore, under the influence of a uniform cyclonic circulation (fig. 1). At this time heavy rains began along the Pacific Coast. This precipitation was produced by a combination of several factors, each contributing to the rainfall. In this section, we will investigate the various elements in detail.

In Washington, Oregon, and northern California, topography plays a most important role in the rainfall distribution. From the rugged Pacific coastline, elevations of the Coast Range in southern Oregon and northern California rise abruptly to 5,000- to 7,000-foot peaks. In California, the Sacramento Valley is located between this range and the much higher Sierras. As the Coast Range flattens rapidly to the north, the Cascades become the dominant range running through Oregon and Washington with average elevations of 6,000 to 9,000 feet and peaks extending to 12,000 feet. Mount Rainier just to the west of the range reaches 14,408 feet. Along the Oregon-California border the Coast Range, Cascades, and Sierras merge into one mountainous region. Mount Shasta, elevation 14,162 feet, is the predominate feature here. All these ranges, rising rather precipitously from the Pacific and generally oriented in a north-south direction, constitute an effective barrier against low level winds and moisture.

The rate of orographic precipitation depends largely upon the strength of the flow normal to the mountain barrier [1]. The 5-day mean sea level pressures for the period January 14–18 (fig. 2) indicate west-southwest flow from the Pacific onto the Oregon and northern California coasts. Figure 3 shows that sea level pressures were about 10 mb. higher than normal off the California coast and 5 to 10 mb. lower than normal west of Washington with a strong gradient increase in the area between 40° and 45° N. The intense gradient was not confined exclusively to the surface. The mean 700-mb. chart (fig. 4) and its departure from normal (fig. 5) also indicate excessive west-southwest flow. The jet stream at the 500-mb. (fig. 6) and 300-mb. levels entered the coast in the vicinity of Portland, Oreg., during the period January 17–19. This shows that winds were strong at all levels with the maximum winds zone sloping to the north with altitude.

Martin and Hawkins [3] have drawn "wet" and "dry" composite charts for Eureka, Calif. Their charts are based on the departures from normal of the 5-day mean 700-mb. heights. The "dry" chart is dominated by a large area of positive departures from normal along the west coast of the continent. In contrast, the "wet" chart has an intense negative area in the Gulf of Alaska with a slight positive area from southern California southward. Martin and Hawkins state that the cause of heavy precipitation at Eureka is a strong westerly to

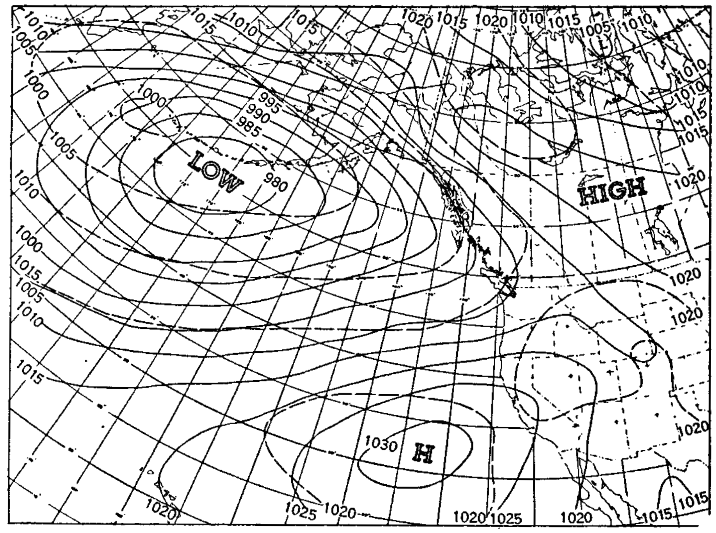

FIGURE 2.—5-day mean sea level isobars (solid lines) January 14–18, 1953, compared with the normal January sea level isobars [2] (dashed lines). Isobars are labeled in millibars.

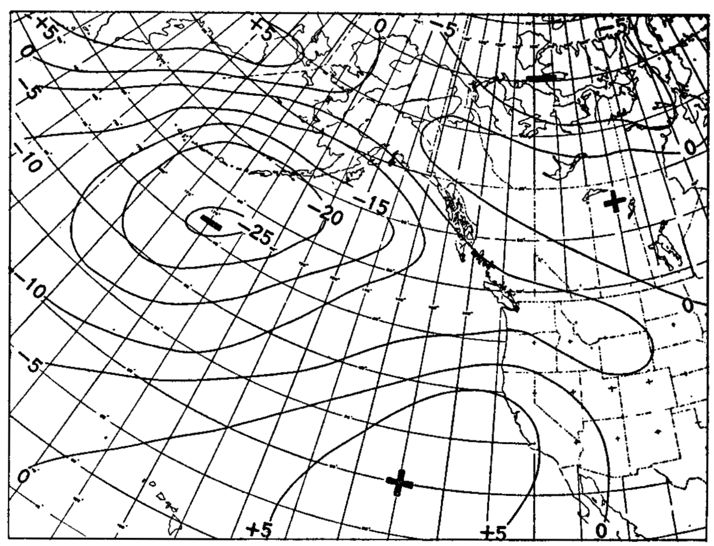

FIGURE 3.—Departure of 5-day mean sea level pressures (mb.) from monthly normal, January 14–18, 1953. Note the indications of a tight gradient between San Francisco and Seattle.

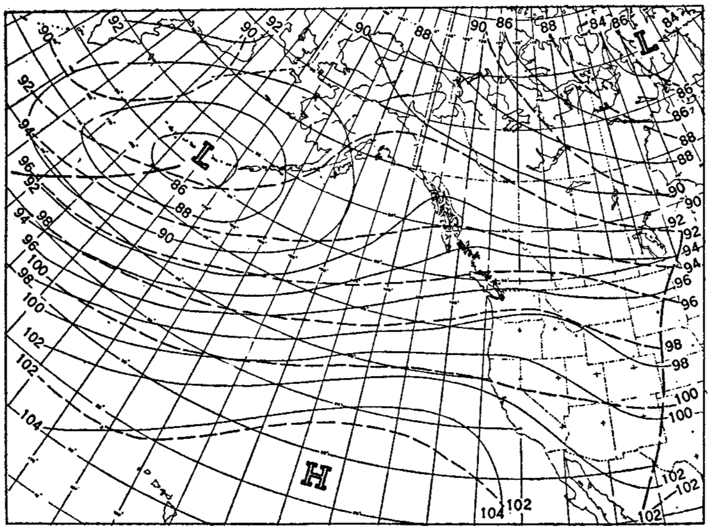

FIGURE 4.—5-day mean 700-mb. contours (solid lines) January 14–18, 1953, compared to the normal January contours (dashed lines) [2]. Heights are labeled in hundreds of geopotential feet. Note that the gradient between San Francisco and Portland, Oreg., is twice the normal.

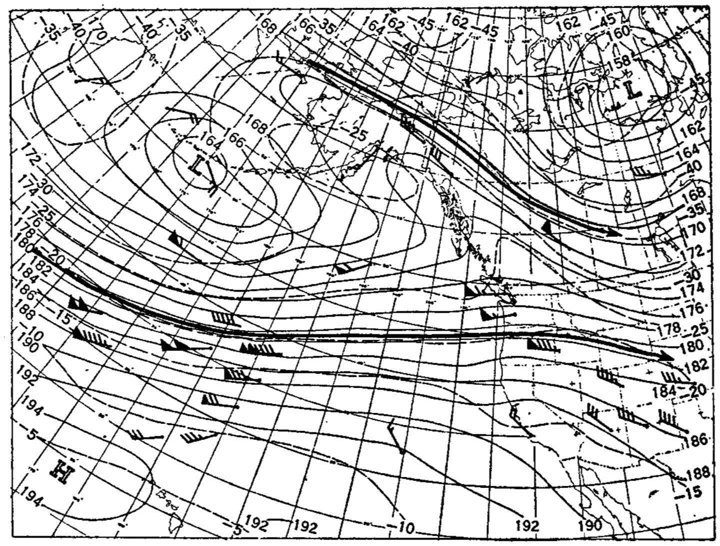

FIGURE 6.—500-mb. chart for 0300 GMT, January 18, 1953. Contours (solid lines) are labeled in hundreds of geopotential feet, isotherms (dashed lines) in ° C. Note that the maximum winds zone (heavy lines) enters the coast near Portland, Oreg.

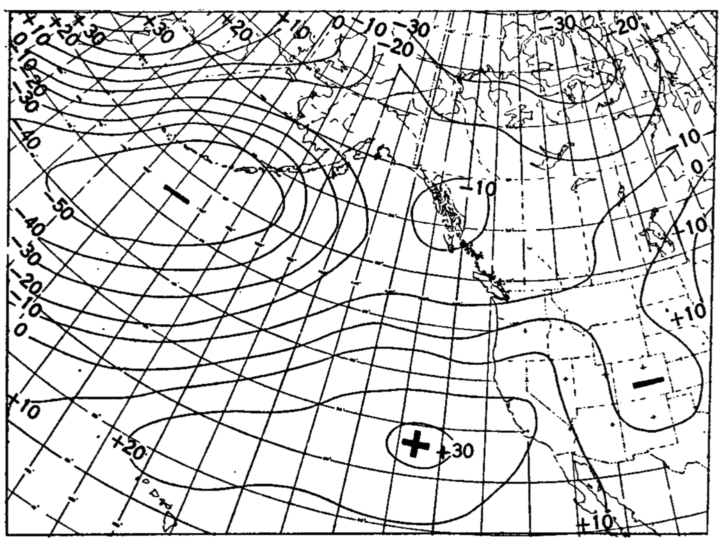

FIGURE 5.—Departure from normal of 5-day mean 700-mb. heights (tens of geopotential feet), January 14–18, 1953. The magnitude of the negative area near the Aleutians agrees well with Martin and Hawkins "wet" type chart [3].

southwesterly flow of moist Pacific air, a condition which was met in the January case, as may be seen in figure 5. In addition they have presented a graph for estimating the total 5-day precipitation for Eureka by use of two parameters, first, the departure from normal of the contour gradient between 50° N., 130° W. and 30° N., 110° W. and second, the height anomaly intermediate between these two points at 40° N., 120° W. From this graph the estimated total 5-day precipitation for the case under discussion is about one-third of what actually occurred. The difference must be due to factors other than gradient, perhaps above normal moisture.

Throughout the 3-day period under consideration, and during the preceding week, frontal systems were entering the coast approximately one per day. These systems were forming as waves on the polar front about 1,000 miles northwest of the Hawaiian Islands (fig. 1). Originating from a position more southerly than usual and imbedded in the large cyclonic flow aloft in existence over the Pacific, these waves were accelerated east-northeastward and occluded as they approached the Washington-Oregon coast. In general, the fronts were extremely difficult to follow especially after they moved inland. Examination of the hourly rainfall totals indicates that precipitation was fairly uniform during these three days with only slight maxima concurrent with the frontal passages. One might conclude, therefore, that the fronts were of minor importance in producing the rain.

Since the strength of the flow against the mountains has been established, and the effect of the frontal systems minimized, we shall investigate the origin of the air mass with particular emphasis on moisture and stability. Cold polar air masses moving off Alaska or Asia over the warmer waters of the Pacific Ocean are modified by warming and increasing moisture in the lower layers. The amount of modification varies directly with the length of trajectory over the water; a shorter trajectory, from Alaska or Canada to the West Coast and then inland, favors a more convectively unstable air mass [1]. Tropical air masses moving northward are cooled from below, thus becoming stabilized in the lower layers and actually losing a small amount of moisture by condensation.

A study of the upper air soundings at Medford, Oreg. (not reproduced), shows that the temperatures at 500 mb. were too cold to be of tropical origin, and therefore must have been from a polar source. These same soundings show high moisture content below 500 mb.—evidence that the polar air had a long maritime trajectory. Examination of figures 1 and 3 indicates that such air would have originated over Alaska or more likely Siberia, then moved

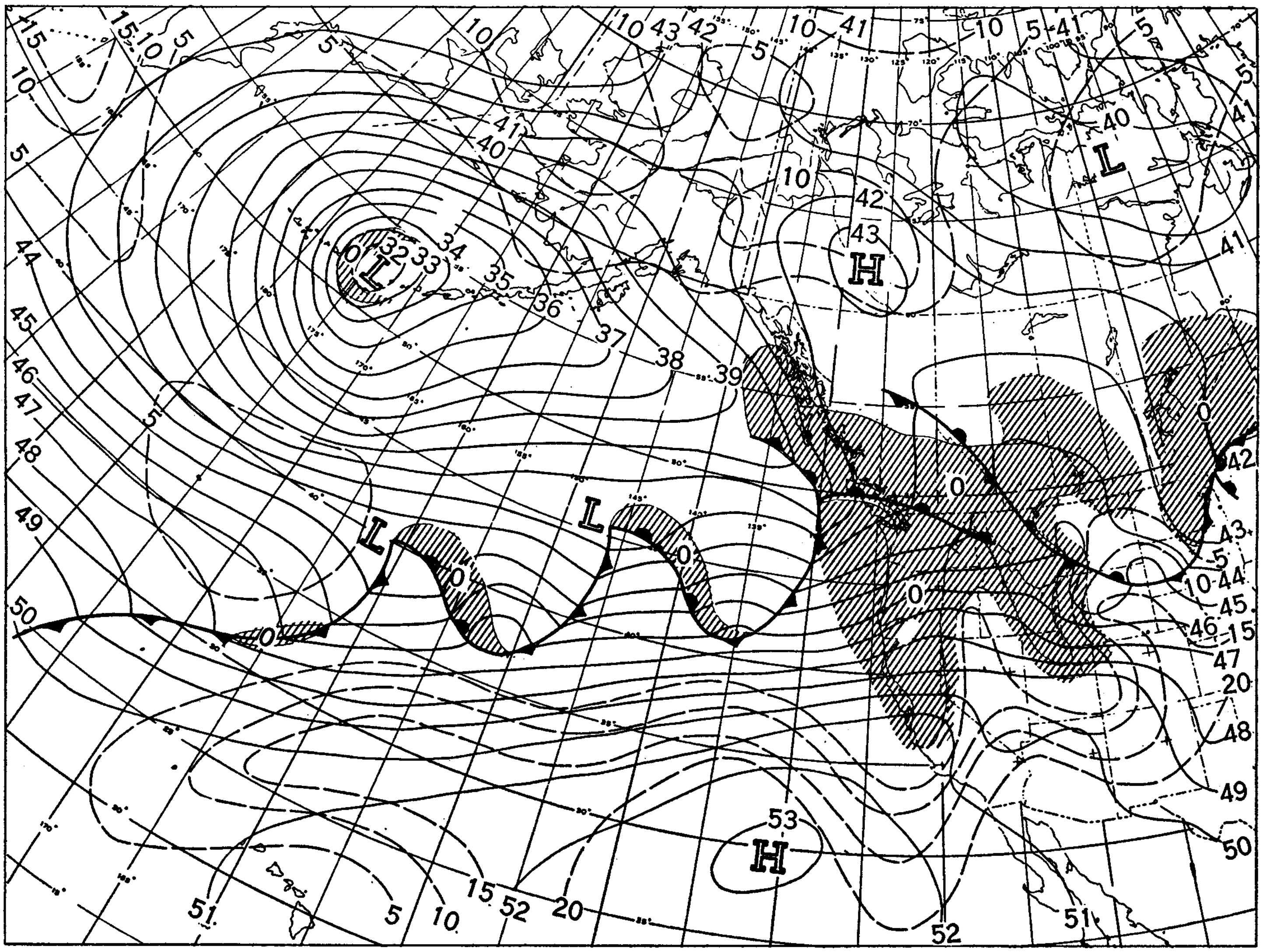

FIGURE 7.—850-mb. chart, 0300 GMT, January 19, 1953. Contours (solid lines) are labeled in hundreds of geopotential feet. Dew point depressions, $T-T_d$, (dashed lines) are in ° C. with areas of zero depression shaded.

southward to the region northwest of the Hawaiian Islands, and finally, modified considerably in its lower layers, advanced toward the West Coast from the southwest. Air with this history would be quite moist and conditionally unstable, i. e., identified as mPk becoming mTk.

The surface layer was unusually moist as indicated by 60° F. dew point temperatures reported by ships along the coast. Lines of equal dew point depression ($T-T_d$), a measurement of saturation, at the 850-mb. level (fig. 7) show the presence of a moist tongue along the frontal zone. It is common knowledge that West Coast rainfall is directly related to the gradient and moisture. Putting this to practical use, forecasters in the area employ a quantitative precipitation forecasting graph,[1] which relates expected rainfall amounts to predicted winds and surface dew points. Several objective methods for forecasting precipitation at West Coast cities have been developed using the parameters of gradient and moisture. Others rely primarily on pressure gradient (for example see Thompson [4]).

Surveying the above conditions we find a combination of strong west-southwest winds, coastal mountain ranges, and a moist unstable airmass. The coalition of these factors is repeatedly found along the West Coast during frontal passages. However, it is unique for this combination to persist over a particular area for a prolonged period. Usually the area of tight gradient and associated orographic rainfall will migrate from Washington southward to California with the period of appreciable amounts lasting less than 24 hours at any one locality. In this specific case the strong flow of moist air normal to the northern California-Oregon coastal mountains persisted for three days with only slight fluctuations due to the numerous frontal passages.

[1] T. E. Jermin, W. O. Peterson, and others, "Rainfall Computation Charts, Seattle Forecast District", Seattle, Nov, 1948. (Processed manuscript.)

PRECIPITATION

Except for moderate rains in western Washington, the first week of January was relatively dry. During the second week, rainfall increased to average amounts with peaks on January 9 and 10. Moderate to heavy rains beginning on the 16th, continued uninterruptedly through the 19th. The area most affected by this precipitation comprised the western portions of Washington, Oregon, and northern California. For the period 17th–19th, the amounts varied from 14.17 inches at Cape Blanco, Oreg., on the coast to a probable maximum on the western slopes of the Coast Range, and dropped to less than 1 inch east of the mountain barriers. The precipitation was above normal both for the month and for these three days in the area enclosed by the 1 inch isohyet (fig. 8). In fact, some stations (see table 1) reported 3-day totals 6 to 10 times and monthly totals 2 to 3 times the normal. Cape Blanco, Oreg., recorded the greatest 24-hour total, 7.66 inches, beginning at 1230 GMT on January 17. Along the coastal slopes from North Bend, Oreg., to Fort Bragg, Calif., amounts of over 3 inches were measured. These excessive totals were the chief factor contributing to the resulting floods.

As mentioned before and as shown in figure 8, the greatest concentration of rainfall occurred near the coastal section where the initial effects of friction and maximum lifting were combined with the tight gradient. Figure 9 illustrates the close relationship between pressure gradient and precipitation. This precipitation is also related closely

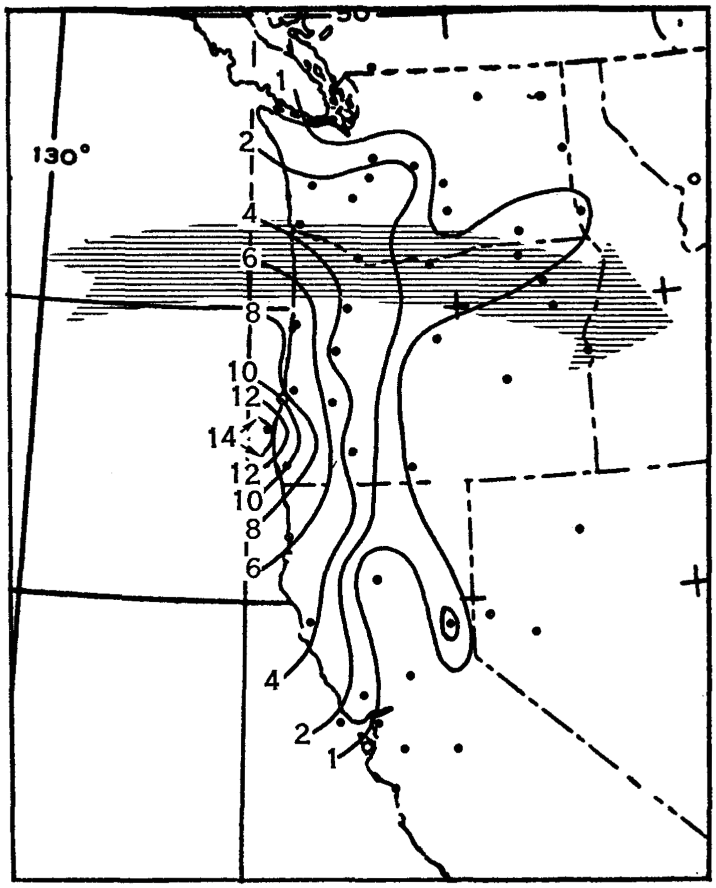

FIGURE 8.—3-day rainfall isohyets (inches) for 1230 GMT, January 16, 1953, to 1230 GMT, January 19, 1953. Hatched arrow indicates mean 300-mb. jet during the same period. The heaviest rain fell south of this zone.

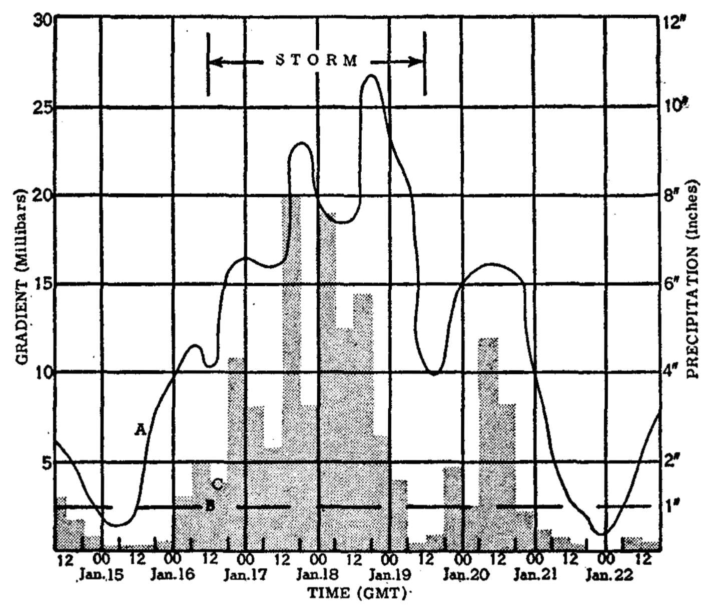

FIGURE 9.—Composite graph showing gradient between San Francisco and Portland, Oreg. (A), normal January gradient between San Francisco and Portland (B), and the combined totals of 6-hourly precipitation (C) at the following coastal stations: Fort Bragg, and Eureka, Calif., Brookings, Cape Blanco, North Bend, and Newport, Oreg. Note the relationship between gradient and precipitation.

TABLE 1.—*Precipitation at selected stations, January 1953*

Station	Total month	Departure from normal	3-day total 17-18-19 (0800-0800 GMT)	3-day normal [6] 17-18-19	$\frac{\text{3-day total}}{\text{Total month}} \times 100$ percent
					Percent
Spokane, Wash	4.56	+2.84	0.55	0.16	12
Seattle, Wash. (FOB)	10.93	+6.44	1.16	.42	11
Tacoma, Wash	9.57	+4.60	1.08	.48	11
Ellensburg, Wash	3.01	+1.81	.69	.12	23
Olympia, Wash	19.84	+13.15	2.14	.60	11
Yakima, Wash	2.67	+1.71	.49	.09	18
Lewiston, Idaho	2.88	+1.83	.73	.10	27
Kelso, Wash	12.24	+7.14	1.53	.45	12½
Walla Walla, Wash	4.52	+2.84	1.15	.15	26
Pendleton, Oreg	2.88	+1.40	1.13	.15	39
Portland, Oreg. (CHB)	14.67	+9.24	2.23	.51	15
Meacham, Oreg	9.29	+4.99	3.50	.42	38
Salem, Oreg	15.40	+9.68	2.80	.54	18
Baker, Oreg	1.40	+.39	.43	.11	31
Eugene, Oreg	11.13	+5.72	2.51	.51	23
Burns, Oreg	1.98	+.51	.75	.12	38
Roseburg, Oreg	10.16	M	3.06	.45	30
Sexton Summit, Oreg	10.14	+6.12	3.49	.39	34
Medford, Oreg	5.49	+2.98	2.32	.24	41
Mt. Shasta, Calif	8.38	+3.84	1.51	.42	18
Eureka, Calif	12.63	+6.43	5.92	.60	47
Red Bluff, Calif	3.56	−.17	.76	.36	21
Blue Canyon, Calif	19.10	+9.93	4.17	.90	22
Sacramento, Calif. (POB)	3.51	+.65	.58	.27	17
San Francisco, Calif. (FOB)	3.26	−.77	.72	.39	22
Oakland, Calif	2.04	−1.26	.49	.30	24

to the jet stream, which, in conjunction with these other factors determined the heavy rainfall pattern. In this particular case, the mean upper-level jet stream was located north of the maximum precipitation (fig. 8). This bears out what Starrett [5] found in a detailed study, that precipitation activity tends to be in the vicinity of the jet stream in the westerlies.

On the 20th the deep Low near the Aleutians started filling, thus decreasing the strong zonal flow over the Pacific and West Coast. The Gulf of Alaska Low then deepened and a warm ridge moved in over California forcing frontal systems to enter the United States in the vicinity of the Canadian border. Although heavy rains occurred on the 20th and 21st along the Oregon coast, they generally were north of the flood areas. By the 22d, all rain had ceased in California and most of Oregon.

FLOODS

Because of moderate rainfall during the 2d week of January, the runoff index factor was high. Thus subsequent precipitation was converted almost entirely into flooding. Although the snow line was high and coverage lighter than usual, the abnormally warm temperatures would have melted enough snow to augment stream flow. Supersaturated soil conditions, snow melt, and the heavy rains combined to cause flooding on practically every river and stream in northwestern California, western Oregon, and southwestern Washington. These inundations began almost simultaneously on the smaller streams with the onset of the heavy rains and continued through the 21st on the larger rivers. Many high water records were broken. On the Klamath River, near Klamath, Calif., the January 18 discharge was 280,000 second-feet (preliminary provisional data) compared with the previous peak flow of 197,000 second-feet on February 2, 1952. Similarly, the Salmon River at Somesbar, Calif., attained a maximum rate of 41,000 second-feet on the 18th, almost 11,000 second-feet greater than the previous record on December 28, 1945 [7]. In Oregon, the Rogue River reached its highest level since 1927. Of the larger rivers, the Willamette was above flood stage, while the Columbia overflowed from Vancouver, Wash., to the Pacific Ocean [8].

The damage was due primarily to erosion, although rising waters routed several thousand families from their homes and destroyed much personal property. The erosion consisted mainly of earthslides and washouts, disrupting railroad and highway traffic. In California, damage to the road systems was estimated to be between 2 and 3 million dollars in Humboldt and Del Norte counties alone, inducing the Governor to declare a state of emergency there. Northwestern Pacific Railroad officials reported approximately 50 slides and washouts blocking 265 miles of track in Oregon and California. A huge slide of mud and rock swept a locomotive into the Eel River near Scotia Bluff, Calif., resulting in 3 fatalities. A few small mountain communities were isolated for several days with food supplies running perilously low. News reports and photographs revealed swirling waters as high as the second floor of many homes. In coastal areas, evacuation of these homes was hampered by gale-like winds and 5-foot waves. These conditions prevailed over a large area during one of the worst floods in that particular region.

ACKNOWLEDGMENTS

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REFERENCES

1. Hydrometeorological Section, U. S. Weather Bureau, in cooperation with the Corps of Engineers, U. S. Army, "Maximum Possible Precipitation over the Sacramento Basin of California," *Hydrometeorological Report No. 3*, U. S. Waterways Experiment Station, Vicksburg, 1943.
2. U. S. Weather Bureau, "Normal Weather Charts for the Northern Hemisphere," *Technical Paper No. 21*, Washington, D. C., 1952, pp. 7, 19.
3. D. E. Martin and H. F. Hawkins, Jr., "Forecasting the Weather—The Relationship of Temperature and Precipitation over the United States to the Circulation Aloft," *Weatherwise*, vol. 3, No. 6, Dec. 1950, pp. 140–141.
4. J. C. Thompson, "Progress Report on an Objective Rainfall Forecasting Research Program for the Los Angeles Area," U. S. Weather Bureau, *Research Paper No. 25*, Washington, D. C., 1945.
5. L. G. Starrett, "The Relationship of Precipitation Patterns in North America to Certain Types of Jet Streams at the 300-Millibar Level," *Journal of Meteorology*, vol. 6, No. 5, Oct. 1949, pp. 347–352.
6. U. S. Weather Bureau, Normals of temperature and precipitation. (Latest computation, to be published.)
7. Weather Bureau Office, Medford, Oreg., Monthly Flood Report, January 1953. (Unpublished).
8. Weather Bureau Office, Portland, Oreg., Flood Report—Portland, Oreg., River District, January 1953. (Unpublished.)